ECL 205

A VERSATILE BOOM HELPS CAT MECHANICS

Mel Kruschke invented and fabricated a versatile, labor-saving boom system for Peterson Tractor Co.'s field mechanics. Their increased efficiency let Peterson provide faster, more extensive on-site maintenance for its customers.

The assistance of Mr. Mel Kruschke and the engineering staff at Peterson Tractor Co. is gratefully acknowledged.

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In the fall of 1966, Don Loan, Service Manager at Peterson Tractor Co.'s main shop in San Leandro, California, called in his field mechanics. The company was going to purchase some new field service vehicles and wanted suggestions for improving the existing trucks and equipment. He especially wanted to hear from Mel Kruschke, a field mechanic who had just recently transferred from Peterson's shop in Chico. Mel had made extensive modifications to his own rig, and Don wanted to determine if the benefits of incorporating these changes on all of the company's trucks warranted the costs.

Peterson Tractor Co. is the dealer and distributor for Caterpillar products in Northern California. Their customers use Caterpillar's heavy equipment and engines in all types of operations including excavating and highway construction, land clearing and logging, refuse compaction, and for marine, industrial, and hospital emergency power plants. In each of these operations, machine down time can be costly in idle man hours and tardy production schedules. For this reason, Peterson Tractor considers customer service to be a major aspect of its business.

It is often too costly and time consuming to transport a large machine to a shop for repairs. This is especially true if the machine is badly needed at the job site. With this in mind, Peterson employs a team of field mechanics, each with his own field service turck. Their purpose is to make repairs or replace required parts on equipment at the job site, thus minimizing down time.

Peterson's problem was to properly equip these mechanics to do their jobs without excessive cost to the company. Peterson's heavy lift truck (Exhibit 1) had an adequate boom load capacity, but its cost prohibited the purchase of an entire fleet. Also, field mechanics required this maximum boom capacity on only a small fraction of their jobs. The company had decided, therefore, to equip a standard one and a half ton vehicle with a hand operated boom for normal loads, and leave the standard service truck on call for larger jobs.

Mel Kruschke had been a field mechanic for over 15 years. His modifications reflected his ideas on what capabilities a field truck should have. It needed sufficient area in the bed for spare parts as large as entire engines; a boom capable of lifting these parts from the bed and placing them advantageously for installation; and controls which would facilitate its operation by one man.

The trucks now in use had several disadvantages. The side boxes for tools and auxiliary equipment restricted the driver's view as he tried to back the boom into position. Although the base of the boom was movable, this was a purely manual operation which the mechanics avoided when possible. The same was true of telescoping the boom to lengthen it. The maximum extension of the boom for highway travel, both in height and to the rear of the truck body (4 feet max), was fixed by law. As a result, most field operations were accomplished with the boom at the highway length and in the highway position fore and aft.

With the boom in this position, the mechanic often found himself working with a very short hoist line. This made lateral adjustment of the position of a heavy load by even a few inches a strenuous job. A higher boom or some method of changing the lateral position of the tip of the A frame would alleviate this problem. Lateral adjustment of the hoist hook was nearly always necessary due to the difficulty of backing the truck on uneven terrain and without the assistance of a guide.

When loading large parts into the truck, the boom was raised nearly to the vertical position. Even then, only the rear half of the truck bed was accessible to the hoist line. More than once, in trying to place a part as far forward as possible, an operator had taken the boom past the vertical position with catastrophic results to the boom, truck cab, and engine or other part on the hoist line.

As can be seen from Figure 1, the angle (c) between the boom and boom line for this service truck was small. Mel realized that this put too great a load on the boom line. Note that the boom line (35) attaches to the boom at its apex (30). The hoist line (32) is a separate line or chain come along. Both lines were manually operated.

Mel gave Don Loan a brief demonstration of those changes he had already incorporated into his rig. He was somewhat skeptical of gaining acceptance for his suggested modifications and thought no more of the meeting. Don surprised him by incorporating into the new trucks many of the suggestions of the mechanics at the meeting. The operators' field of vision was improved and space was provided in which auxiliary equipment could be stored. Don then asked Mel to take one of the modified truck bodies and build a boom which would incorporate all of his ideas. Exhibit 2, taken from Mel's patent, gives detailed views of this new system which is now

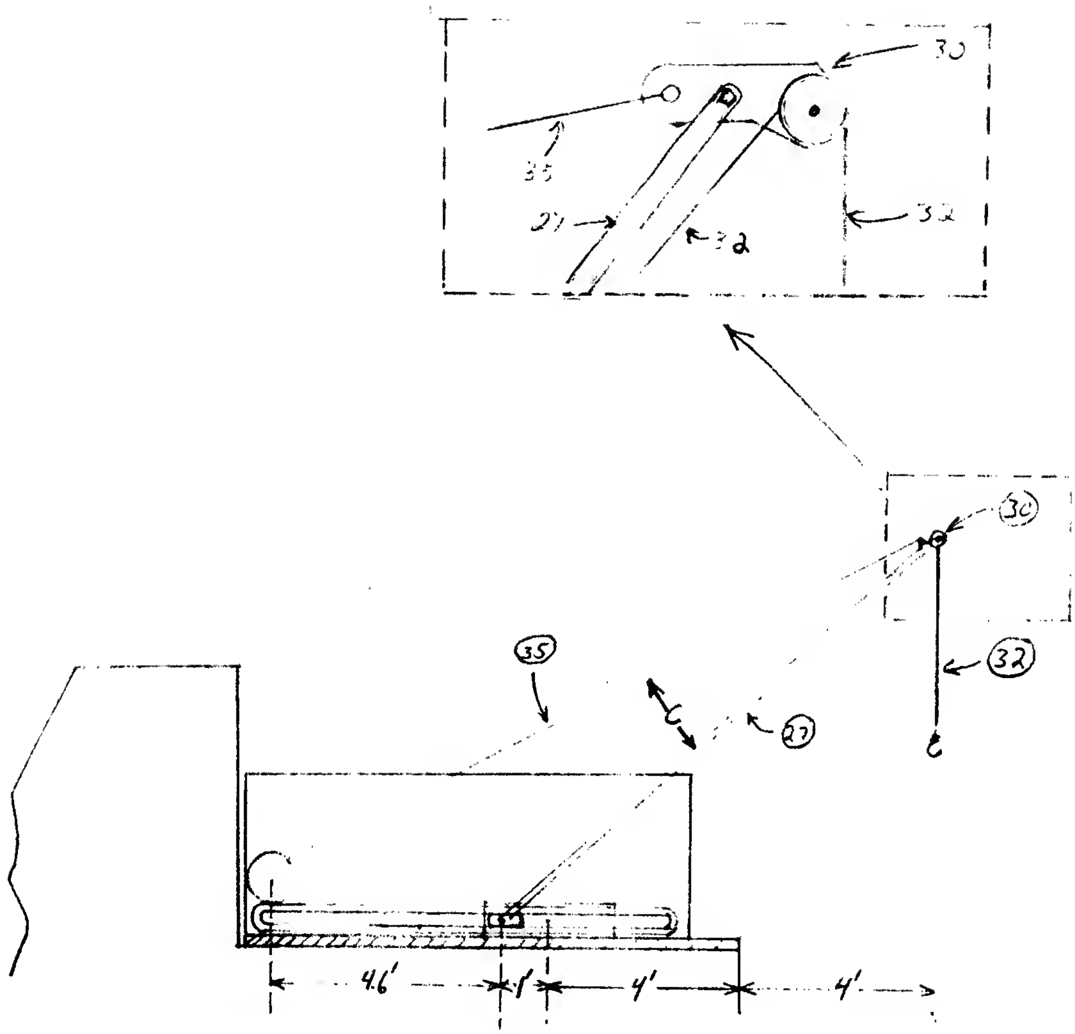

Figure 1: Field Service Truck with Old Boom

in use by Peterson Tractor Co.

Mel designed his boom to be completely powered. The heart of the system consists of three electric motors and two automotive differentials. One motor operates the hoist line, one adjusts the inclination of the boom, (length of boom line), and the third powers a chain drive which adjusts the position of the boom legs fore and aft in the travel guides. Remote control switches allow the mechanic to make these adjustments from his location on the machine being repaired.

The cable drums for the hoist line and boom line and the chain drive for the travel chain were all linked through the differentials. The hoist line or boom line could be adjusted independently, but if the travel switch was depressed, all three functions were activated simultaneously. Mel arranged the gears so that a load would travel an essentially horizontal path into or out of the truck without operating three separate controls. This ingenious triple function linkage greatly reduced the complex manipulations formerly required in loading and unloading spare parts.

Lengthening the boom is still a manual operation (although some of the mechanics have now rigged a compressed air assist to this function). Since the boom is so easily moved, however, the mechanics can now travel legally with a longer boom stowed further forward in the truck. This decreases reliance on changing boom length.

To align the boom laterally over the job, Mel added a hydraulic linear actuator to the right leg of the A frame. This device changes the length of the leg, shifting the tip of the boom as much as a foot to either side.

The travel guides were raised, and built into the side tool boxes. This adds height to the boom, further decreasing the need to telescope it. The boom line had to be rerouted, however, so that a large angle between the line and the boom could be maintained. Routing the boom line through a pulley supported over the cab actually increased this angle from what it was on the old system.

Even though additional equipment is required for the new system, the usable floor space in the service trucks is actually enlarged. The motors and required gears are located compactly against the back of the cab, and the raised and recessed position of the travel guides exposes additional floor space. Increased boom mobility allows the mechanic to

reach a far greater portion of this exposed truck bed than was formerly possible.

All parties concerned seem pleased with the new boom system. The mechanics have the satisfaction of using a versatile tool which they helped design. Their increased efficiency enables Peterson's customers to decrease both their down time and their repair bills. The capital cost to Peterson is more than balanced by the increases in the mechanics' productivity and customer satisfaction. Although the boom was fabricated in Peterson's shops, the company released all rights to Mel Kruschke, and paid for the prosecution of a patent on the system in his name.

STUDENT QUESTIONS:

Before deciding to rig all the service trucks with Mel's boom, Don wanted to analyze its design and capabilities. The mechanics would also need to learn new lifting procedures in order to fully exploit the boom's versatility. Use the dimensions of Figure 2 to answer the following questions which analyze the characteristics of the boom system. See Exhibit 2 for greater detail.

Length of each boom leg: 12.2 feet
Distance between boom legs: 4.5 feet at base
Rear wheel contacts ground at Point A

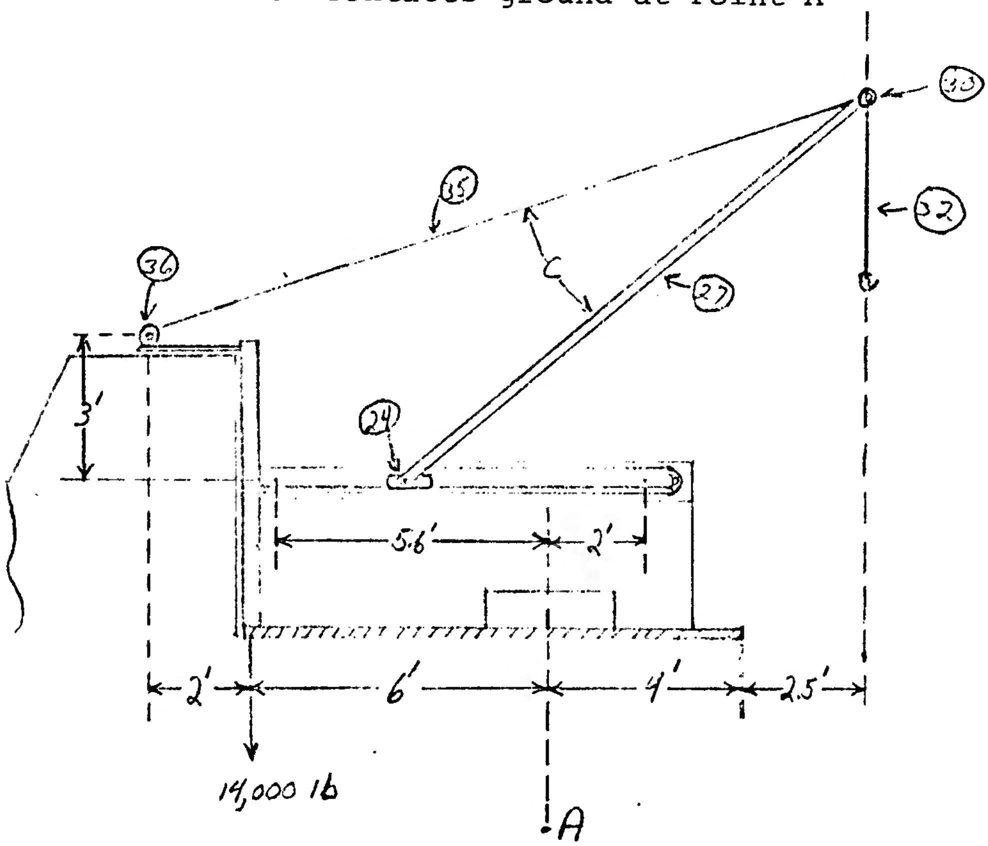

Fig. 2 New Boom System

NOTE: Boom line (35) is attached to the apex of the boom (30). The hoist line (32) runs along the boom leg (27) to its winch (18), shown in Exhibit 2, Fig. 2.

1. Neglecting strength limitations of the system components, what is the maximum load, L, that can be lifted using the new boom if the hoist line (vertical portion) must be located at least 2.5 feet from the rear of the truck? On the same truck would the maximum load of the old boom system be the same? The truck, with tools and equipment, weighs 14,000 lbs. (Fig. 2). Use this load, L, in all of the other questions.

2. Why is a small angle (c) between the boom and boom line a disadvantage? Would varying this angle change the maximum load, L (question 1)?

3. The weakest link in the boom system is the boom line. (The load on the hoist line can be easily reduced through the use of snatch blocks.) Assume a 12,000 lb. load limit on the boom line.

In the "highway position" (base of the boom 1 foot forward of Point A) could the old boom system lift the load L without exceeding the load limit of the boom line? Where should a mechanic position the new boom in order to lift load L with the least force in the boom line? What is this force? Load L remains 2.5 feet from the rear of the truck.

4. Start with the boom in the position you specified in Question 3. What work is done in moving the load L from its suspended position 2.5 feet behind the tailgate to the point where the boom legs reach their forward limit? Mel has designed the system so that the load travels a horizontal path.

What is the force in the boom line when the boom legs reach their forward limit? What operating procedure can be instituted which will insure that the 12,000 lb. limit on the boom line is not exceeded while loading the truck? Support your procedure with calculations. Note: To prevent the boom from going past the vertical position and collapsing on the cab, mechanics were told that the hoist line (vertical portion) must always be positioned at least 2 feet to the rear of the base of the boom legs.

5. Neglect the 12,000 lb load limit on the boom line. As the boom system picks up the load L (2.5 feet from the tailgate) and travels forward, the forces in the boom legs change. Where is this force a maximum? What is its maximum magnitude? What spreading force will be exerted by the boom legs on the travel guides? What vertical force?

6. Is any advantage gained by lengthening the boom prior to unloading a spare part? What advantage does the longer boom give the mechanic while he is positioning the part on a disabled vehicle?

Heavy Lift Truck
Peterson Tractor Co.

EXHIBIT 1

United States Patent

[11] 3,613,918

[72] Inventor Melvin W. Kruschke
37756 Duvall Court, Fremont, Calif. 94536

[21] Appl. No. 883,923
[22] Filed Dec. 10, 1969
[45] Patented Oct. 19, 1971

[54] **FIELD SERVICE VEHICLE**
17 Claims, 11 Drawing Figs.

[52] U.S. Cl. .... **214/75 H,** 212/8, 212/59, 254/184
[51] **Int. Cl.** **B60p 1/54**
[50] **Field of Search** .... 214/77, 75 H, 75; 212/8, 8 A, 59 R

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ABSTRACT: A field service truck having a boom that is movable fore and aft relative to the truck, along a pair of tracks lying above and at the sides of the truck bed, so as not to interfere with the holding capacity of the truck bed A boom motor and winch acts through a cable to raise and lower the boom by swinging it about its lower ends; a hoist motor and winch control a cable for raising and lowering the load picked up by the hoist; and a travel motor acts through a chain drive to move the boom fore and aft of the truck. The travel motor is connected by differentials to the hoist winch and the boom winch, so that the boom can be moved fore and aft without substantially changing its height or the height of the load.

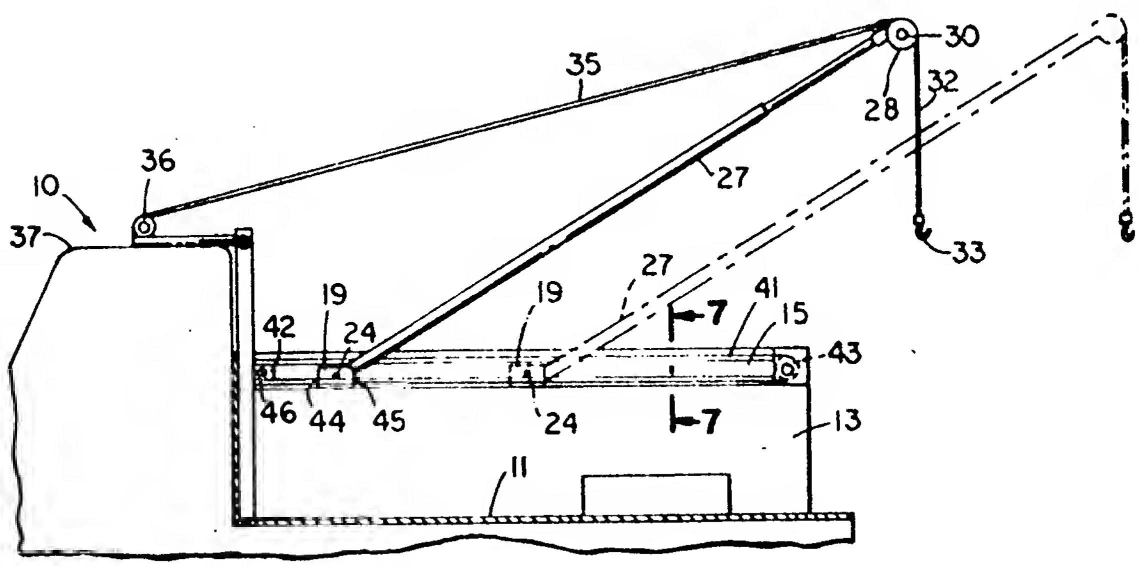

EXHIBIT 2

PATENTED OCT 19 1971 3,613,918

SHEET 1 OF 4

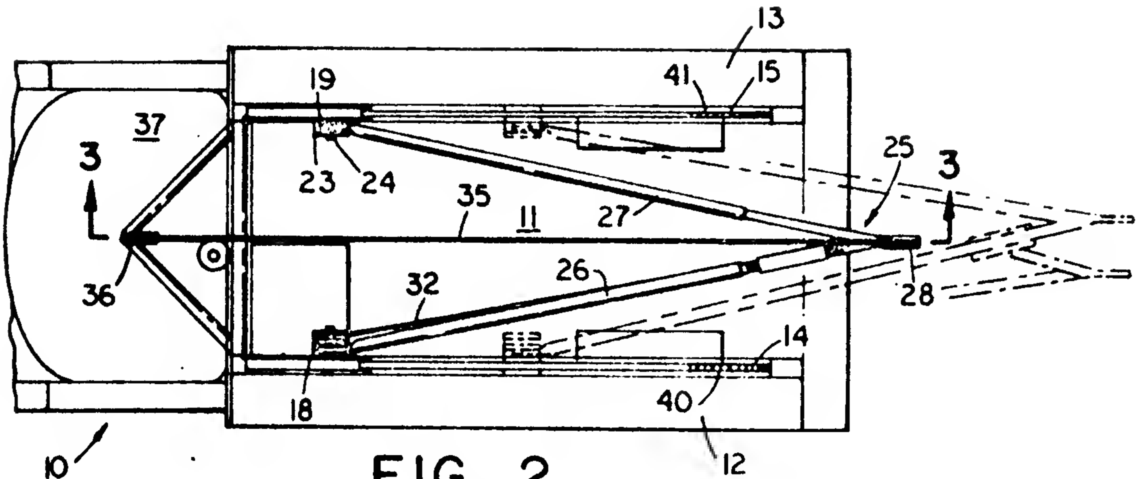

FIG_2

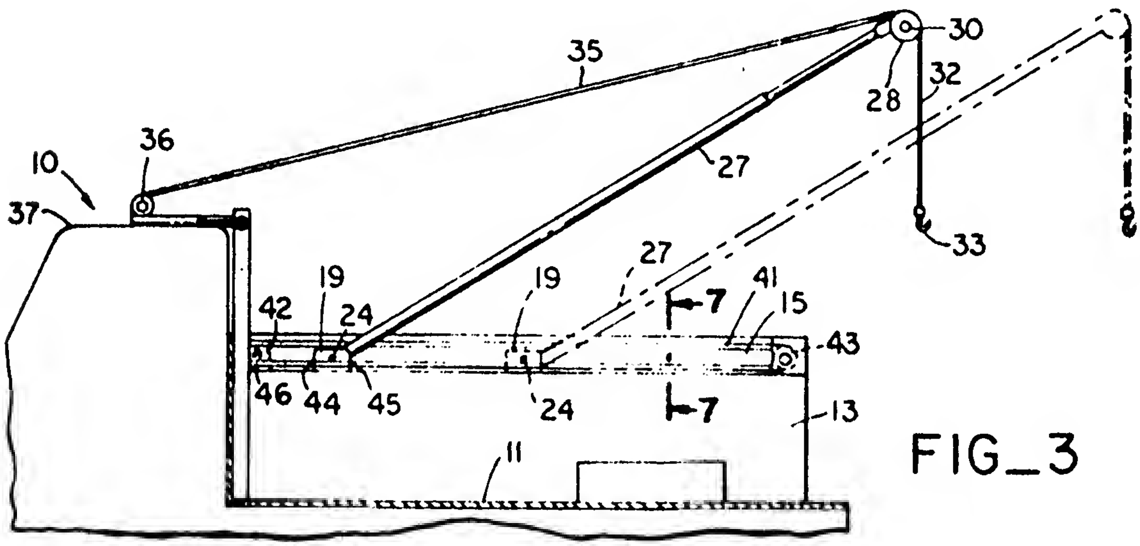

FIG_3

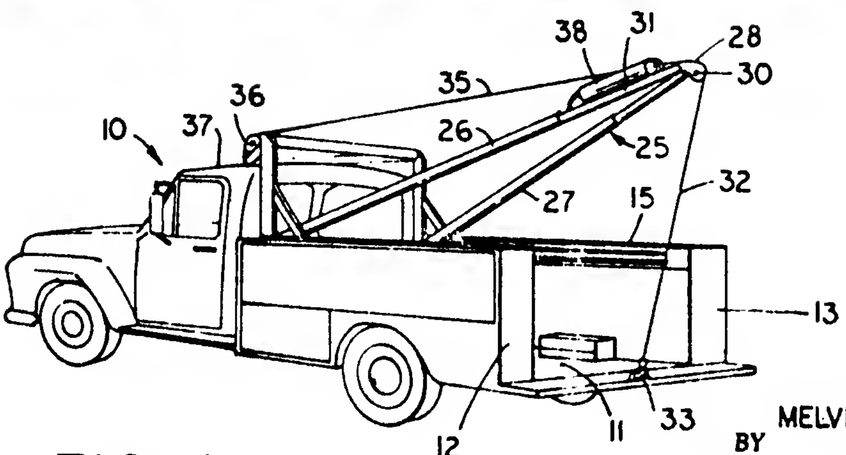

FIG_1

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PATENTED OCT 19 1971

3,613,918

SHEET 3 OF 4

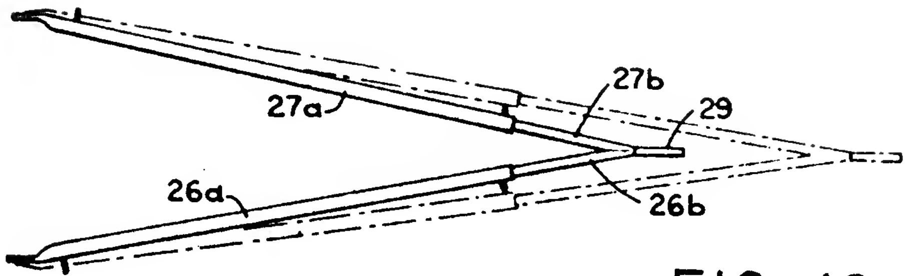

FIG_10

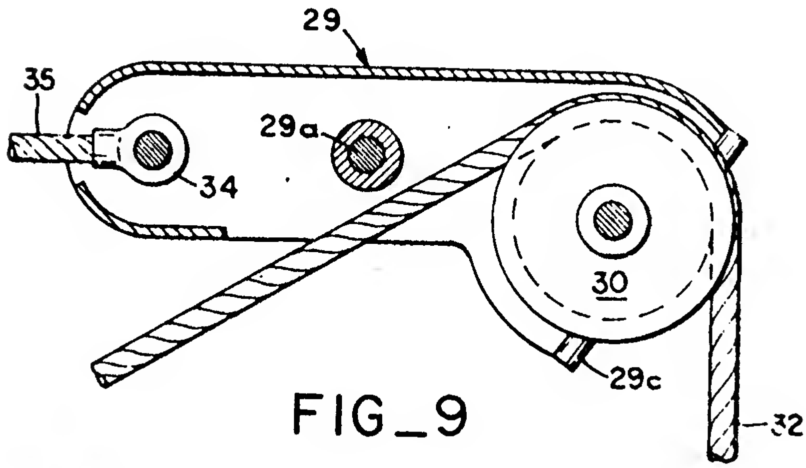

FIG_9

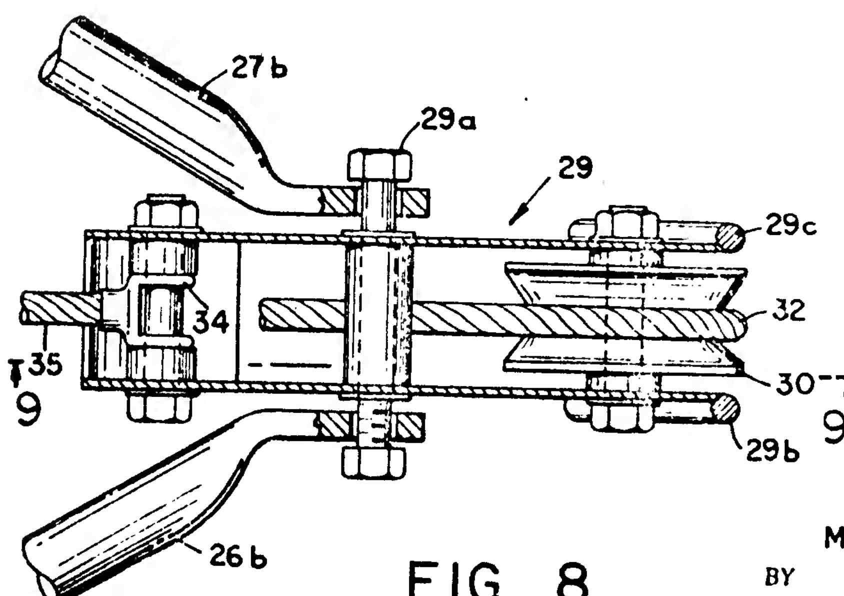

FIG_8

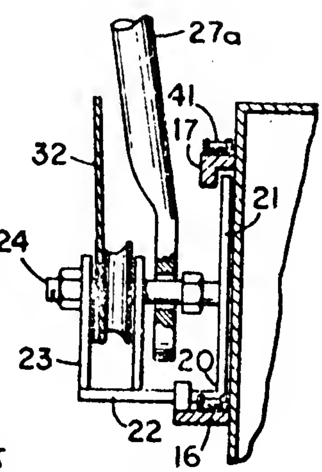

FIG_7

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EXHIBIT 2

Field Service Truck

EXHIBIT 2

INSTRUCTOR'S NOTES

This case will challenge the student's ability to isolate the necessary system components into appropriate free body diagrams. Once successful at this, the questions can be easily answered. Except where noted all references are to Figure 2 shown with the student questions.

1. This is a simple lever problem. The pivot is the point of contact of the rear wheel with the ground, Point A. Any configuration of the boom and boom line will give the same answer for either the old or new boom. Summing moments about A:

$$L = \frac{(14{,}000\ \text{lb})(6\ \text{ft})}{(6.5\ \text{ft})} = \underline{12{,}900\ \text{lbs}}$$

Any additional load would tip the truck. Mechanics do on occasion put blocks under the tail gate to prevent tipping but this practice is not encouraged.

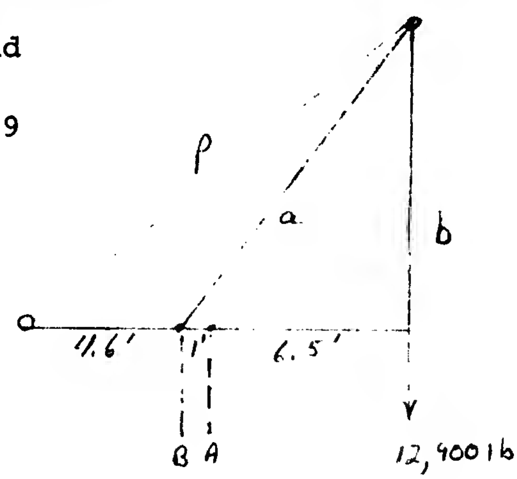
2. Since the boom legs are attached to the travel guides with pin joints, the boom can support no moments. Summing moments about the base of the boom (24) shows that the force in the boom line can be reduced by increasing the angle (c) between the boom and boom line. However, the maximum load L remains the same.

3. Consider the boom to be a rigid body pivoted at B. In the plane of the boom line and the hoist line, the boom length, a, is 12 feet. The only portion of the hoist line exerting a moment at B is the vertical portion. The load L is, in effect, hung from the apex of the boom.

Let P be the force in the boom line. Using the triangle relationships for the old boom,

we find b = 9.37 feet and

(1) $\frac{P_x}{P_y} = \frac{12.1}{9.37} = 1.29$



Then summing moments about B, the base of the boom, gives:

$$\Sigma M_b = 0$$
$$= (12.9K\ lb)(7.5\ ft) - P_x(0\ ft) - P_y(4.6\ ft)$$
$$P_y = 21{,}000\ lb$$
$$P = \left[P_y^{\,2} + (1.29\ P_y)^2\right]^{1/2}$$
$$= \underline{34{,}300\ lb}$$

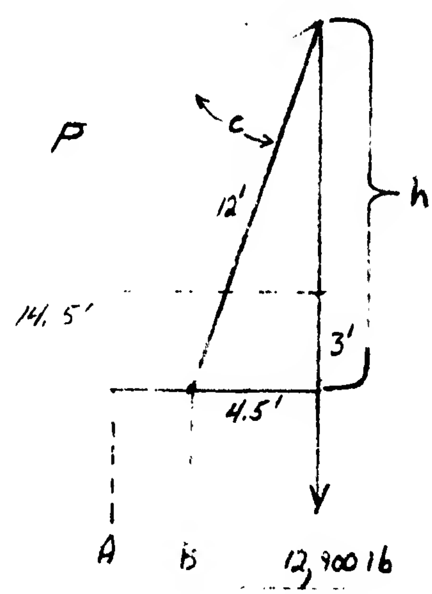
much too high for the boom line.

New boom system: The base of the boom should be moved all the way to the rear of the truck to make angle C as large as possible.

We find h = 11.12 ft,

and that

$$(2)\quad \frac{P_x}{P_y} = \frac{14.5}{8.12} = 1.785$$



$$\Sigma M_b = 0$$
$$= (12.9K\ lb)(4.5\ ft) - P_x(3\ ft) - P_y(10\ ft)$$

Substituting (2) gives:

$$P_y = 3780\ lb$$

Solving for P:

$$P = \underline{7{,}720\ lb}$$

smaller than the limit on the boom line.

The actual cable rating for the boom line was 6500 lbs. working force. Peterson engineers recognized this weakness and recommended doubling the boom line. To do this, the line was routed through a pulley attached to the apex of the boom and then run back to an anchor on the framework over the cab. This reduced the force in the cable by half.

During some maintenance operations a mechanic was required to reach in under the roof of the machine he was repairing. Some boom line failures did occur as a result of these height limitations. To help emphasize the critical nature of boom positioning, Mel, on his own initiative, conducted a training session for the other mechanics. For a training aid he used a toy wrecker which he had rigged with a fish scale on its boom line. By experimenting with this toy, the mechanics could get a better feel for the consequences of boom position without experiencing actual failures.

To further aid the mechanics, Mel installed a cut off switch on each rig at the anchor of the boom line. The switch automatically stopped the three boom motors if the force in the boom line cable exceeded 6,000 lbs. The mechanic could override the switch, but he did so knowing that the total load on the double boom line had reached 12,000 lbs.

4. Since the suspended load travels an essentially horizontal path, the only work required is that needed to overcome friction. The angle of the boom remains constant in this process. The angle c between the boom and the boom line is constantly decreasing, resulting in a boom line force which reaches its maximum as the boom reaches its most forward position.

Using a calculation similar to that for question 3, we find

$P_x = .85P_y$

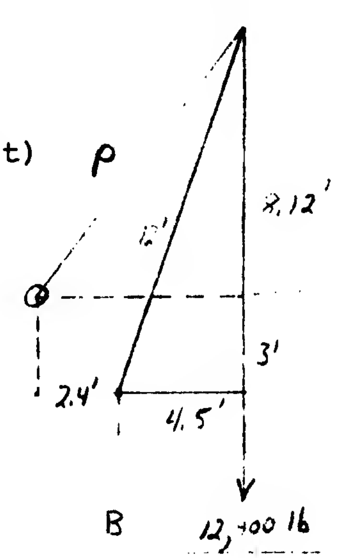
$\Sigma M_b = 0$

$= (12.9\text{K lb})(4.5\text{ ft}) - P_x(3\text{ ft}) - P_y(2.4\text{ ft})$

$P_y = 11{,}700$ lbs

$P = \left[P_y^2 + (.85P_y)^2\right]^{1/2}$

$= \underline{15{,}350 \text{ lb}}$



In order to reduce the force in the boom line, the boom should be brought to a more vertical inclination. This enlarges the angle c and reduces the moment arm of the load L about B. Prior to moving the boom forward in the travel guides, mechanics should change its inclination until the hoist line (vertical portion) is two feet to the rear of the base of the boom legs. Loading the truck with the boom at this angle will cause a maximum force of 7395 lbs in the boom line.

$$P_x = .498\ P_y$$

$$\Sigma M_B = 0$$

$$= (12.9\text{K lb})(2\text{ ft}) - P_x(3\text{ ft}) - P_y(2.4\text{ ft})$$

$$P_y = 6{,}620\text{ lbs}$$

$$P = \left[P_y^{\,2} + (.498\ P_y)^2\right]^{1/2}$$

$$= \underline{7{,}395\text{ lbs}}$$

5. The student should not have to make any calculations to determine the location where the boom legs have their maximum force. Once the load is raised, the contribution of the hoist line force remains constant. Maximum boom leg force, therefore, occurs where there is maximum boom line force. This occurs where there is a minimum angle between the boom and the boom line, the most forward position of the boom. Taking the boom to a more vertical position would decrease the boom leg force.

This question deals with forces in space. By resolving the forces in the boom line (P) and hoist line (H) into their resultant (R) in the plane of the boom legs, the problem can be solved. Let B be the force in each boom leg.

From question 4: $P_y = \underline{11{,}700\text{ lbs}}$

$$P_x = (11{,}700)(.85)$$

$$= \underline{9{,}940\text{ lbs}}$$

The resultant of the boom line and hoist line force:

$$\Sigma F_y = 0$$

$$= -12.9\text{K lb} - 11.7\text{K lb} + R_y$$

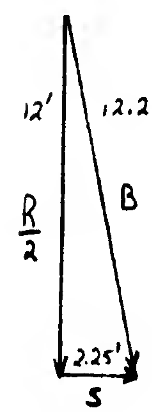
$$R_y = 24{,}600 \text{ lbs.}$$

$$\Sigma F_x = 0$$

$$R_x = F_x = 9940 \text{ lbs}$$

Then $R = \underline{26{,}500 \text{ lbs}}$

Taking advantage of the symmetry of the boom, we construct the force triangle shown, where S is the spreading force.



Then, $$\frac{B}{12.2} = \frac{R/2}{12}$$

$$B = (13{,}250 \text{ lb})\frac{(12.2 \text{ ft})}{(12 \text{ ft})}$$

$B = \underline{13{,}350 \text{ lb}}$ axial compressive force in each leg

The boom can support no bending moment.

Similarly for S:

$$S = (13{,}250 \text{ lb})\frac{(2.25 \text{ ft})}{(12 \text{ ft})}$$

$S = \underline{2{,}480 \text{ lb}}$ on each side of the travel guide.

The vertical force on the travel guides equals R_y, already calculated. R_y = 24,600 lb or 12,300 lb on each travel guide.

It is clear that a 13,350 lb force on the boom leg (3.5" steel pipe) is far from critical. These calculations were necessary, however, so that Peterson engineers could insure that the travel guides were properly supported. They were

also used for checking the shear strength of the pins used to hold the telescoping section of the boom.

6. In order to eliminate other variables from this question, we must assume that the base of the boom remains in the same location, B, regardless of its length. This will fix the moment arm of the spare part about B for any boom length. The angle C, however, will be smaller for the longer boom. The resultant increase in the boom line force is a disadvantage.

If, however, the boom line is not overloaded, the mechanic does gain the advantage of a longer hoist line. This will allow him to expend less of his own force in the final positioning of the spare part. Also the linear actuator will displace the apex of the boom a greater distance with longer boom legs.

NOTE: The boom can only be lengthened manually, while it is horizontal. The mechanic must make this decision, therefore, prior to placing any load on the hoist line.